
Failure of ProFile Ni-Ti instruments used by an inexperienced operator under access limitations

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Abstract

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Aim The purpose of this study was to evaluate the failure incidence of ProFile nickel–titanium rotary instruments (PRI) when used by an inexperienced operator in conjunction with different motors and under limitations of access.

Methodology PRI with 0.06 taper were used by an inexperienced operator in a crown-down technique. The teeth were mounted in resin arches of a phantom head to reproduce limitations of access. In groups 1–4, air, high torque control, low torque control and very low torque control motors were used, respectively. Each group included 30 canals in extracted human molars. One set of PRI sizes 40–15 was used for each canal; the PRI were sterilized before each case. A 2.5% NaOCl solution was used as an irrigant. An inexperienced operator performed all the cleaning and shaping procedures after application

of a rubber dam. The opening of the mouth in the phantom head was standardized for the four groups. The number of deformed and separated instruments was recorded for the various experimental groups and analyzed statistically for significance with chi-square tests.

Results A high incidence of instrument deformation and separation occurred with the air, high torque control and low torque control motors. Only seven and two instruments deformed and separated, respectively, with the very low torque control motor, whereas at least 23 and 10 instruments deformed and separated respectively with the other motors.

Conclusions A very low torque control motor was safer than on air, high torque control or low torque control motors when PRI with 0.06 taper were used by an inexperienced operator in a crown-down manner at 170 rpm.

Keywords: ProFile, nickel–titanium, access limitations, motors, failure.

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Introduction

Instrument separation and deformation are serious concerns in root canal treatment. During shaping, instruments might lock and/or thread (screw) into the canal. Locked instruments are subjected to high levels of stress, frequently leading to separation. Several studies have evaluated the influence of various factors on the fatigue life and resulting separation of endodontic Ni–Ti alloy instruments. In one study (Pruett *et al.* 1997), the authors investigated the effect of the angle

and radius of curvature on cyclic fatigue of Lightspeed rotary Ni–Ti instruments. Ramirez-Salomon *et al.* (1997) evaluated the incidence of Lightspeed separation. Thompson & Dummer (1997, 1998) and Bryant *et al.* (1998) demonstrated that the incidence of Ni–Ti rotary instrument deformation and separation was related to instrument design and instrumentation technique.

The influence of operator experience was assessed in three studies that showed proper tuition or experience was necessary to minimize the incidence of instrument separation (Barbakow & Lutz 1997, Mandel *et al.* 1999, Yared *et al.* 2001a).

Pruett *et al.* (1997) found that the rotational speed did not affect cyclic fatigue of Lightspeed instruments. Gabel *et al.* (1999), and Yared *et al.* (2001a) demonstrated that

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Ni-Ti rotary instrument failures are less likely to occur at a lower rotational speed.

Torque is another parameter that might influence the incidence of instrument deformation and separation. Different types of motors are used in conjunction with Ni-Ti instrumentation. When a high torque control motor is used, the instrument is very active and the incidence of instrument locking and consequently deformation and separation would tend to increase. With these motors, torque at failure of the instrument is often exceeded. Air motors do not allow torque control, and variation in air pressure could affect the rotational speed and consequently torque. For instance, a drop in air pressure would lead to a decrease of torque. The instrument would become less active and the operator would tend to force the instrument into the canal leading to deformation and separation.

Recently, a new generation of low and very low torque control motors has been introduced; torque values as low as 1 and 0 Ncm can be set on the low and very low torque control motors, respectively. These motors take into consideration the low torque at failure values of Ni-Ti rotary instruments. Wolcott & Himel (1997) showed that torque values at fracture for 0.04 taper ProFile nickel-titanium rotary instruments (PRI) sizes 15, 25 and 35 were: 0.21, 0.48 and 1.24 Ncm, respectively. According to Kobayashi *et al.* (1997), torque should be set between 0.40 and 0.80 Ncm for PRI to avoid instrument failure. Svec & Powers 1999 compared the torque at failure values of used and unused PRI and showed that torque at failure was 0.78, 1.06 and 1.47 Ncm for unused 0.04 taper PRI sizes 25, 30 and 35, respectively. Recently, Bortnick *et al.* (2001) demonstrated no significant difference in instrument deformation and breakage between air and electric motors. Yared *et al.* (2001b) evaluated *in vitro* the failure incidence of 0.06 taper PRI when used in conjunction with three different motors and a specific instrumentation technique. Their results indicated no difference amongst the air, high torque control and low torque control motors, when an experienced operator performed the canal preparation.

The purpose of this study was to evaluate the incidence of PRI failures when used by an inexperienced operator, under access limitations, in conjunction with air, high torque control, low torque control and very low torque control motors.

Materials and methods

Extracted human mandibular and maxillary first and second molars with mature apices and mesial or buccal

roots demonstrating curvatures greater than 25° (Schneider 1972) were used; the teeth were kept in 10% formalin at 37 °C. Access openings were made, the canal orifices located and the chamber irrigated with 2.5% NaOCl. Patency of the canals was determined with a size 6 K-type file (Dentsply Maillefer, Ballaigues, Switzerland). Only canals having a snug fit with an 8 or 10 K-type file were included. The snugness indicated that the canal was narrow and suitable for inclusion in the study. The working length of each canal was determined by passing a size 6 K-type file to the apical foramen and then subtracting 0.5 mm. The working length and reference points were recorded for each canal. Initial radiographs were taken from the buccal and proximal directions and exposure time and processing were standardized. The radiographs were used to detect canals that joined each other. In these cases, only one canal was included in the study. The angle of curvature and the radius of curvature were determined on the initial buccal radiograph using the method of Pruett *et al.* (1997). Canals were ordered according to radius of curvature (least to greatest), then randomly and blindly assigned into four groups, such that all ranges of radii of curvature were equally represented in each group, and such that each group included 30 canals. Wax was placed on the tip of the roots of each tooth. Each tooth was mounted in a maxillary resin arch containing all maxillary (resin) teeth except for tooth 17. The mandibular molars included in the study were also mounted in the maxillary resin arch with the mesial canals directed buccally. The maxillary and the mandibular resin arches were mounted in a phantom head. The degree of mouth opening of the phantom head was standardized for the four groups. A rubber dam was placed and retained on the experimental tooth with a clamp.

In the four groups, 25 mm long PRI with a 0.06 taper, sizes 40–15 were used in a crown-down technique sequentially in a descending order of size. In group 1, the PRI were placed in an air motor (Model 324, Micro-Mega, Besançon, France) with a contra-angle (6:1) reduction handpiece, set at 166.67 rpm. Placing the handpiece of the air motor on the 'Turtle' setting and placing the indicator on 1000 the speed is determined. Air pressure at full rheostat depression was 40 psi. In group 2, the PRI were used in a handpiece in conjunction with a high torque motor (Nouvag TC 3000, Nouvag, Goldach, Switzerland). The torque on this motor was set at 10 Ncm. This motor allows torque to be set at very high levels varying from 10 to 55 Ncm. The rotational speed was set at 170 rpm. In group 3, the PRI were used with

a low torque motor (Nouvag Micromotor TCM Endo 2, Nouvag, Goldach, Switzerland) that allowed low torque values (settings 1, 1.5, 2 and 3). According to the manufacturer, these settings correspond to torque values of 1, 1.5, 2 and 3 Ncm, with a range between 1 and ~12 Ncm (corresponding to setting 8). The speed on this motor was set at 170 rpm. This motor had an auto-torque reverse function. In group 4, the PRI were used with a new generation very low torque control motor (Tecnika, ATR, Pistoia, Italy). This motor allows very low torque values (<1 Ncm). It also has an auto-torque reverse function. This motor was used with the torque values set by the manufacturer. The speed on this motor was set at 170 rpm.

The series of PRI were used according to the following guidelines: the apical pressure exerted on the PRI was light and each instrument was used for only a few seconds in the canal; the PRI were used with small in and out movements. Only one buccal canal was prepared in each molar. After the first sequence of PRI, the apical width of the canal was checked with a size 15 hand file. At this stage, canals were excluded from the study if the size 15 file reached the working length and was loose in the canal. The canals were then enlarged until a size 25 PRI reached the working length. Three to five recapitulations (waves) with PRI sizes 40–15 were required to complete cleaning and shaping of each canal. Preparation was complete when a 1-1 Machtou plugger (ISO size 50) penetrated to 5–7 mm short of the working length, and a fine-medium gutta-percha cone fitted 0.5 mm short of the working length. During shaping each canal was irrigated with 5 mL of 2.5% NaOCl using a 0.625-in. 27-gauge needle placed as far into the canal as possible without binding. The patency of the apical foramen was frequently checked by passing the tip of a size 8 K-type file through the foramen.

Before each use, the PRI set (kit) was sterilized by steam autoclave for 5 min at 135 °C; the whole cycle of sterilization lasted 35 min. One set of PRI sizes 40–15 was used for each canal. Thirty sets of six PRI taper 0.06 instruments were included in each of the four groups. A 2.5× magnification was used to check for

instrument deformation after each passage. An operator blinded to the study performed the instrument inspection. Instrument deformation and separation within each group were recorded. In case of instrument deformation before completing the cleaning and shaping, the instrument was replaced. In case of instrument separation, the cleaning and shaping was stopped. Prior to instrumentation of canals, each set of PRI was used according to the sequence, by an endodontist experienced with the instrumentation technique, to prepare five curved canals in endodontic resin blocks. Each set was then blindly assigned to one of the three groups if all the instruments did not show any deformation or separation.

The same operator, a 4th year undergraduate student, performed the cleaning and shaping procedures in all the canals of the four groups. This student, not familiar with the Ni-Ti rotary instrumentation, followed a theoretical course on the technique and practiced on seven endodontic resin blocks. The canals in group 4 were first prepared followed by the canals in groups 3–1.

Only the overall number of deformed and separated instruments in the different groups was analyzed statistically for significance with chi-square tests.

Results

The mean and standard deviation of the curvature angle and radius of the four groups are listed in Table 1. The mean angle of curvature and the mean radius of curvature were 41.3° and 5.75 mm for group 1; 42.0° and 5.40 mm for group 2; 43.5° and 5.69 mm for group 3; and 41.9° and 5.28 mm for group 4, respectively. The size of deformed and separated instruments within each group is displayed in Table 2 and Table 3. Size 15 instruments deformed significantly more than the other instruments in groups 1–3 but not in group 4. Also, size 15 instruments separated significantly more than the other instruments in group 1 only. The number of deformed instruments in each group is listed in Table 4. Thirteen, 10 and 10 instruments fractured in groups 1–3, respectively; only two instruments fractured in group 4 (Table 4).

Table 1 Mean and standard deviation of the angle and radius of curvature of the four experimental groups

	Group 1	Group 2	Group 3	Group 4
Angle of curvature (degrees)	41.3 ± 1.31	42.0 ± 1.63	43.5 ± 1.32	41.9 ± 1.63
Radius of curvature (mm)	5.75 ± 0.28	5.40 ± 0.19	5.69 ± 0.18	5.28 ± 0.21

Table 2 Incidence of instrument deformation in the four groups

Deformation	Group 1	Group 2	Group 3	Group 4
Size 15	25/55†	11/41	13/43	4/34
Size 20	17/47	7/37	10/40	2/32
Size 25	7/37	5/35	3/33	1/31
Size 30	7/37	6/36	0/30	0/30
Size 35	0/30	1/31	0/30	0/30
Size 40	1/31	2/32	0/30	0/30
Total	32/237	32/212	23/206	7/187

†Number of deformed instruments/absolute number of applied instruments (30 + number of new instruments replacing deformed instruments).

Table 3 Incidence of instrument separation in the four groups

Separation	Group 1	Group 2	Group 3	Group 4
Size 15	8/55†	4/41	5/43	2/34
Size 20	2/47	1/37	3/40	0/32
Size 25	2/37	3/35	1/33	0/31
Size 30	1/37	2/36	1/30	0/30
Size 35	0/30	0/31	0/30	0/30
Size 40	0/31	0/32	0/30	0/30
Total	13/237	10/212	10/206	2/187

†Number of separated instruments/absolute number of applied instruments (30 + number of new instruments replacing deformed instruments).

Table 4 Incidence of instrument deformation and separation in the four groups

	Group 1	Group 2	Group 3	Group 4
Deformation	32/237*	32/212†	23/206‡	7/187
Separation	13/237**	10/212††	10/206‡‡	2/187

*Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.005$.

**Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.025$.

†Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.005$.

††Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.05$.

‡Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.01$.

‡‡Significant difference with group 4; $\alpha = 0.05$; $df = 1$; $P < 0.05$.

Discussion

Torque is one amongst many parameters that might influence the incidence of instrument locking, deformation, and separation. Theoretically, an instrument used with a high torque (motor) is very active and the incidence of instrument locking and consequently deformation and separation would tend to increase. Whereas a low torque would reduce the cutting efficiency of the

instrument, and instrument progression in the canal would be difficult; the operator would then tend to force the instrument and may encourage instrument locking, deformation, and separation. Torque control motors allow the setting of torque generated by the motor. In low torque control motors, torque values set on the motor are supposed to be less than the value of torque at deformation and at separation of the rotary instruments. In high torque control motors, the torque values are relatively high compared to the torque at deformation and at separation of the rotary instruments. During root-canal preparation all the instruments are subjected to different levels of torque. If the level of torque is equal or greater than the torque at deformation or at separation the instrument will either deform or separate. Theoretically, with the low torque control motors, the motor will stop from rotating and can even reverse the direction of rotation when the instrument is subjected to torque levels equal to the torque value set on the motor. Thus, instrument failure would be avoided, whereas, with high torque control motors, the instrument torque at deformation and at separation would be reached before the relatively high torque value set on the motor. Consequently, the instrument would deform and separate. However, the results of a recent study (Yared *et al.* 2001b) did not indicate a difference between high and low torque motors with respect to instrument failure. In that study, the operator was experienced with the use of PRI.

This is the first comprehensive study that evaluated the incidence of Ni-Ti rotary instrument failures when used in conjunction with different types of motors and under access limitations.

The authors had the impression that it would be more interesting to compare the motors using used ProFile. Differences in the incidence of instrument locking, deformation and separation amongst the different motors could have been masked if new instruments were used in each canal. For this reason, each set was used in resin blocks according to the described technique and by the same operator. The number of recapitulations for each instrument was in a similar range when preparing the five root canals in resin blocks.

In the present study, apical enlargement was kept as small as practical according to the principles of Schilder (1974) and because in the opinion of the authors any greater apical enlargement should have been completed with hand instruments.

As in recent studies (Yared *et al.* 1999, 2000, 2001a), it was impossible to standardize the number of recapitulations (waves). Canal width and anatomy influenced the

frequency of recapitulations needed before a size 25 PRI reached the working length. However, 3–5 recapitulations were sufficient for all the canals.

The instruments were inspected for deformation with $2.5\times$ magnification after each passage in the canal. In a previous study, we noted that deformations went undetected if magnification was not used (Yared *et al.* 2000). The use of a dental operating microscope, where available, might decrease the incidence of false negatives (undetected deformations).

The manufacturer recommends using the ProFile instruments at speeds between 150 rpm and 300 rpm. The rotational speed was set at 170 rpm. Previous studies have shown significantly less Ni-Ti rotary instrument failures at slower speeds (Gabel *et al.* 1999, Yared *et al.* 2001a). Yet, it should be noted that the use of a slow speed could have masked any differences amongst the motors.

The torque value (10 Ncm) set on the motor of the second group was the lowest allowed by this motor. In the third group, the torque value was set at 2 Ncm. This motor allowed different low torque settings (1, 1.5, 2 and 3 Ncm). In a pilot study, we noticed that at settings equal to or lower than 1.5 Ncm the rotation of the files was frequently reversed. With the air motor torque control was not possible.

Wolcott & Himel (1997) showed that the torque at fracture for 0.04 taper ProFiles sizes 15, 25 and 35 were: 0.21, 0.48 and 1.24 Ncm, respectively. In laboratory experiments, Kobayashi *et al.* (1997) indicated that the torque threshold for the auto-torque reverse mechanism in the Tri Auto ZX (Morita, Japan) for PRI taper 4% should be set between 0.39 and 0.78 Ncm. Svec & Powers (1999) showed that torque at failure was 0.78, 1.06 and 1.47 Ncm for unused 0.04 taper ProFile rotary Ni-Ti instruments sizes 25, 30 and 35, respectively. Consequently, it was expected that the present study would show a significantly higher incidence of instrument failures especially with the air, high torque control and low torque control (Nouvag) motors. With the air motor, torque control was not available. Instruments could have been subjected during instrumentation to torque levels exceeding their torque at failure values. Also, with the air motor, the rotational speed might not be constant. A sudden increase in the speed (due to air pressure variation) would result in a rapid increase of the torque to which the instrument was subjected (Kobayashi *et al.* 1997) leading to instrument failure. The results of the present study confirmed those of Bortnick *et al.* (2001) who demonstrated that the incidence of instrument deformation and separation is similar for air and high torque control motors.

In groups 2 and 3, the torque setting on the motors was relatively high (10 and 2 Ncm, respectively) (Wolcott & Himel 1997, Kobayashi *et al.* 1997, Svec & Powers 1999). Expectedly, the incidence of instrument deformation and separation was significantly higher with these motors than with the very low torque control motor. In a recent and similar study, instrument separation did not occur with the low torque control motor (Nouvag Micromotor TCM Endo 2, Nouvag, Goldach, Switzerland). The difference can be explained by variation in the methodology: inexperience of the operator and instrument stress due to access limitations in the present study.

Sattapan *et al.* (2000) showed that torque at failure was significantly higher than torque during instrumentation. In the present study, the instruments were used with a slight apical pumping as in the study of Sattapan *et al.* (2000); thus, it seems that torque during instrumentation by an inexperienced operator could have been higher in the four groups than the torque at failure of the specific instruments. This fact would account for the high incidence of instrument failure in groups 1–3. In group 4, the very low torque control motor contributed to limit the incidence PRI failure.

A high incidence of instrument deformation and separation occurred in groups 1–3. The operator probably exerted excess apical pressure on the PRI (Kobayashi *et al.* 1997) and/or used them for too long in the canal. Consequently, these PRI locked into the canal and were subjected to a high level of torque; failure occurred instantly. In group 3, the instruments were subjected to torque greater than their torque at fracture which is probably less than the torque set on the motor (Wolcott & Himel 1997, Svec & Powers 1999). So, the instrument fractured before the motor reversed the rotation direction. In group 4, the torque set on the motor was probably less than the torque at fracture of the PRI. Consequently, the motor reversed the direction of rotation. High stress on the instrument was avoided reducing the incidence of instrument failure. This aspect is very important especially for students and inexperienced operators, and in clinical situations where the instruments might be subjected to increasing stress due to limitations of access.

The results from Table 2 indicated that the size 15 instruments were more prone to deformation than the other instruments when used in conjunction with air, high torque and low torque control motors. Also, there was a trend toward deformation with the smaller instruments except when a very low torque motor was used. Also, the size 15 instruments separated more frequently

than the other instruments when an air motor was used (Table 3). Consequently, it may be prudent to consider the size 15 ProFile with a 0.06 taper a disposable instrument. Similar findings were reported by Bortnick *et al.* (2001) with respect to the size 20 ProFile with a 0.04 taper.

Conclusions

The results of the present study suggested that a very low torque control motor was safer than on air, high torque or low torque control motors when PRI taper 6% were used by an inexperienced operator at 170 rpm and under limitations due to access.

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